The Mars Pathfinder Mission

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The Mars Pathfinder Mission was successfully launched on December 4, 1996, from the Cape Canaveral Air Station. This project is part of NASA's Discovery Program. Discovery Program missions are designed to accomplish focused scientific objectives within a development period of less than 36 months and a total cost through launch plus 30 days of $150 million or less. The spacecraft will arrive at Mars on July 4th and land in the Ares Vallis region to perform surface operations for at least 30 Martian days.

The primary engineering objective of the Mars Pathfinder mission is to demonstrate low cost cruise, entry, descent, and landing systems required to place a payload on the Martian surface in a safe operational configuration. Science objectives include the deployment and operation of various science to characterize the Martian atmosphere during descent and from the surface, as well as characterization of rocks and soil near the lander. Pathfinder is also a key element for NASA's long term Mars exploration program, enabling a cost effective implementation of future Mars lander missions. This paper will discuss the concept of the mission, its current status and key results from the project's engineering and scientific investigations.

Spacecraft Description

The Pathfinder spacecraft consists of a cruise stage and a lander vehicle encapsulated within a protective aeroshell (Figure 1). The cruise stage provides guidance, navigation, attitude control, telemetry, and power generation during the cruise period from Earth to Mars. Power is provided by a solar array covering the top surface of the cruise stage. Attitude determination sensors include a Magellan-heritage star tracker and 5 Sun sensors. The propulsion system consists of four titanium tanks containing 90 kg of hydrazine propellant connected to two clusters of four 4.45 N thrusters. A conical medium-gain antenna is housed on the top face of the cruise stage for communication during cruise. The radio transponder and transmitter along with the attitude control and data handling electronics and software are located within the lander and connect to the cruise stage via a cable harness.

Entry, Descent and Landing

The cruise stage is jettisoned 30 minutes before arrival at Mars and the aeroshell directly enters the Martian atmosphere at velocity of 7.3 km/s. The aeroshell's velocity is reduced by sequential application of aerodynamic braking, a parachute, deceleration rockets, and finally four airbags to null the remaining vertical and horizontal velocity at surface impact. Both the heat shield and parachute are derived from Viking heritage. The heat shield provides protection from extreme temperatures expected during atmospheric deceleration. The parachute is then deployed at a desired dynamic pressure value determined from accelerometer measurements. The heat shield is then jettisoned and the lander is lowered below the backshell on a 20 meter tether. A radar altimeter located on the bottom of the lander is activated to determine the time of retrorocket firing. The Kevlar-coated airbags are inflated 2 seconds prior to retrorocket firing. The tether is then cut at the lander, leaving the retrorockets to carry the parachute, backshell, and tether away while the lander falls to the surface at less than 20 m/see

Surface Operation

After coming to a rest on the surface, the airbags are deflated and retracted. The three side petals are deployed, establishing an upright configuration (Figure 2). Power for the lander is provided by solar arrays mounted on the exposed surfaces of the lander petals. Auxiliary power is provided by a 40 amp-hour silver-zinc rechargeable battery. The Attitude and Information Management Subsystem (AIMS) performs all lander computing functions during all mission phases. AIMS uses a 32-bit IBM RAD 6000 computer with 128 Mbytes of dynamic RAM for data storage, and 4 Mbytes of programmable read-only memory (PROM) for program and critical data storage. Direct communication with Earth is performed through either a steerable high gain antenna or an omni-directional low gain antenna. Other radio hardware includes a Cassini X-band transponder, a solid-state power amplifier, a command detection unit (CDU), and a telemetry modulation unit (TMU). In addition, an auxiliary transmitter (AXT) and second TMU are available as a low-power backup system.

The microrover (named “Sojourner”) is a partially autonomous, 10 kilogram vehicle (Figure 3). It can traverse up to 100 meters from the lander and examine rocks and soil up close using a series of cameras. The microrover uses a six wheel rocker bogey suspension and a sophisticated set of on-board sensors to move around on the Martian surface. It is powered by solar array mounted atop the suspension system, generating 15 W-hours at peak power. Batteries are also carried by the rover for night operations or for additional power when navigating rough terrain. The rover has a 0.1 mips 80C85 computer used for autonomous navigation and control of other rover functions. It communicates with the lander via an UHF modem link. The rover payload consists of fore and aft cameras, the APXS and its deployment mechanism (described below), and other engineering instrumentation to measure the performance of rover mechanisms.

Science Objectives

The science objectives of the mission are to obtain data on the structure of the Martian atmosphere along the entry and descent trajectory, to characterize the landing site surface geology and morphology at sub-meter scale, to monitor meteorological conditions at the landing site, and to investigate the elemental composition of rocks and surface materials at the landing site. The instrument suite used to satisfy these objectives includes the Imager for Mars Pathfinder (IMP), an Alpha-Proton-Xray Spectrometer (APXS) and a facility Atmospheric Structure/Meteorology (ASI/MET) package.

The IMP is a stereo CCD imaging system with color capability provided by a set of twelve selectable filters for each of two camera channels. The camera is mounted on a one meter deployable mast and uses azimuth and elevation drives to obtain panoramic images of the landing site. Surface imaging will be used to study geologic processes and surface-atmosphere iterations.

The APXS is an elemental composition instrument consists of alpha particle sources and detectors for back scattered alpha particles, protons, and x-rays. It is mounted on the microrover to make use of the rover's mobility. The instrument can identify and determine the amounts of most chemical elements based on the interaction of alpha particles with sample material. APXS is mounted on the rover with its sensor head contained in a deployment mechanism that places it in contact with rock and soil surfaces.

The ASI/MET subsystem acquires atmospheric information during the descent of the lander through the atmosphere and during the entire landed mission. Temperature and pressure sensors are located aboard the lander at locations suitable for measuring descent and post-landed conditions, ASI also uses spacecraft accelerometers to measure acceleration and deceleration during the dynamic entry profile. Data collected by ASI/MET will be used to construct profiles of atmospheric pressure, temperature, and density as a function of altitude. After landing, pressure and temperature measurements are made to establish the diurnal variations and the day-to-day variations of the atmospheric boundary layer at the landing site.

Mission Status

As of March 28, 1997, the spacecraft is more than halfway through a seven month Earth-Mars cruise phase. The vehicle follows a Type 1 Earth-Mars transfer trajectory, and will arrive at Mars on July 4, 1997 at 16:52 UTC. All early cruise activities have been completed, including initial spacecraft checkout, health checks of the science instruments and the microrover, and the first two Trajectory Correction Maneuvers (TCM's). The flight team has resolved an anomaly in the attitude control sun sensor that was discovered shortly after launch, and expects that the remainder of cruise will be relatively quiescent, The team is now focusing on detailed planning for atmosphere entry and surface operations. Two more TCM'S will occur on May 7th and June 24th to fine-tune the flight path for a nominal atmosphere entry angle of -14.2 degrees.

Current plans calls for deployment of the microrover and camera on landing day. Sojourner will make daily traverses for at least seven days and obtain several APXS spectra of rocks and soil. The IMP will acquire several multi-color panoramas of the surrounding terrain as well as isolated high resolution images to support rover and APXS operations. Most of the significant science objectives of the mission can be completed within 30 days, but an extended mission of up to one year is possible.

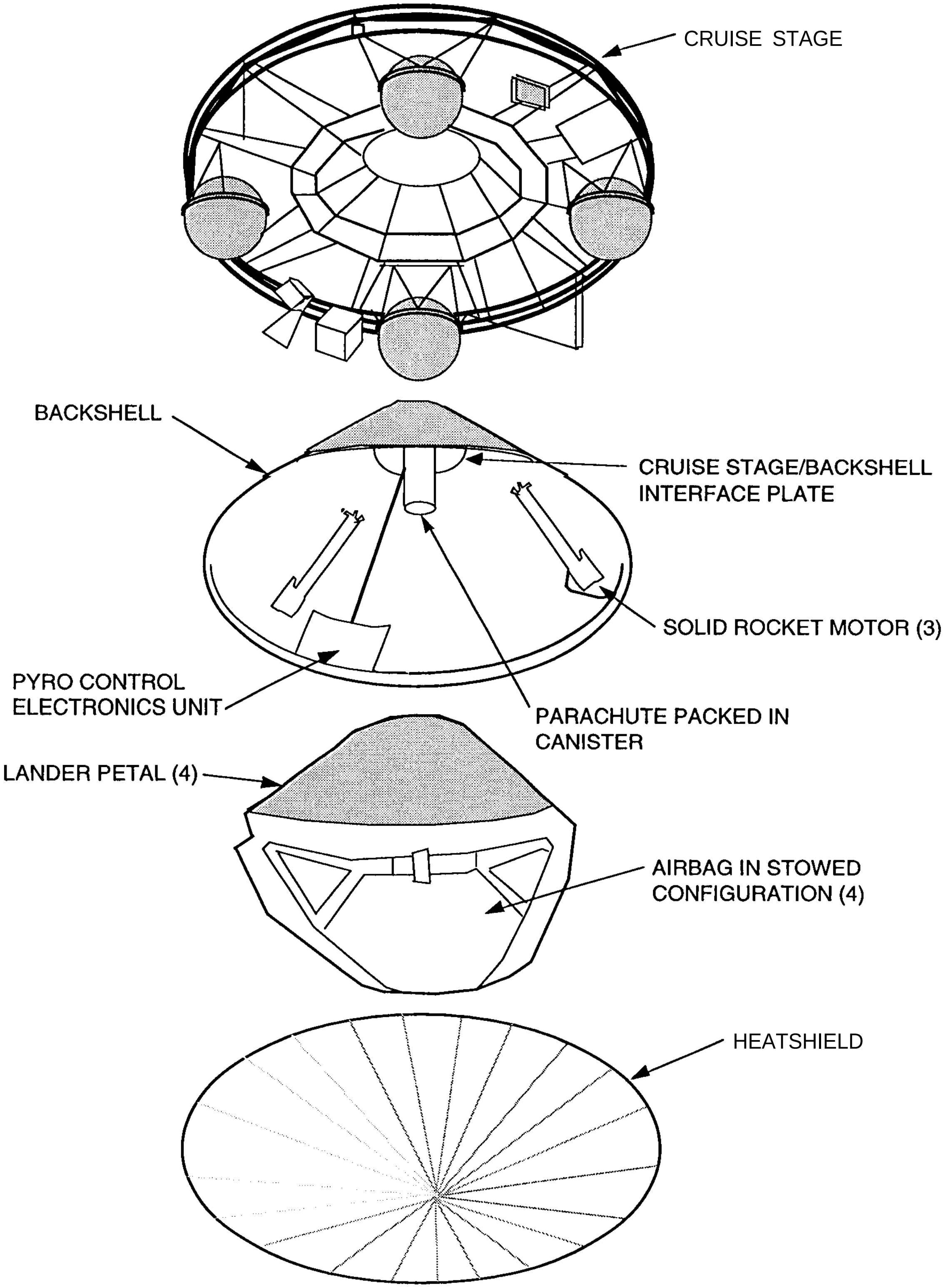

Figure 1- Exploded view of Mars Pathfinder Flight System (Cruise Configuration).